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RESEARCH MEMORANDUM

LATERAL-CONTROL INVESTIGATION AT TRANSONIC SPEEDS OF RETRACTABLE SPOILER AND PLUG-TYPE SPOILER-SLOT AILERONS ON A TAPERED 60° SWEPTBACK WING OF ASPECT RATIO 2

TRANSONIC-BUMP METHOD

By Alexander D. Hammond and James M. Watson

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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LATERAL-CONTROL INVESTIGATION AT TRANSONIC SPEEDS OF RETRACTABLE SPOILER AND PLUG-TYPE SPOILER-SLOT AILERONS ON A TAPERED 60° SWEPTBACK WING OF ASPECT RATIO 2

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SUMMARY

An investigation utilizing the transonic-bump technique through a Mach number of 0.619 to 1.167 has been made in the Langley high-speed 7- by 10-foot tunnel to determine the lateral control characteristics of retractable spoiler and plug-type spoiler-slot ailerons. The wing had a sweepback of 60° at the quarter-chord line, an aspect ratio of 2, a taper ratio of 0.6, and an NACA 65A006 airfoil section parallel to the free stream.

The plug-type spoiler-slot aileron was more effective in producing roll than the retractable spoiler aileron throughout the Mach number, projection, and angle-of-attack ranges investigated. The plug-type spoiler-slot aileron exhibited a large increase in aileron effectiveness at the higher angles of attack over the effectiveness at zero angle of attack up to a Mach number of 0.959.

The use of downgoing spoilers on one wing in conjunction with upgoing spoilers on the other wing increased the aileron effectiveness at low angles of attack but was ineffective or reduced the aileron effectiveness at high angles of attack.

The yawing moments were generally favorable for both the retractable spoiler and plug-type spoiler-slot ailerons.

INTRODUCTION

The use of spoiler-type ailerons on highly swept thin wings looks attractive from both the hinge-moment and wing-flexibility point of view. Considerable work has been done relative to type and location of spoilers on both straight and swept wings (refs. 1 to 6). This paper presents the results of an additional investigation, made in the Langley high-speed 7- by 10-foot tunnel utilizing the transonic-bump technique, of retractable spoiler and plug-type spoiler-slot ailerons on a highly sweptback wing. In addition to determining the effect of a slot behind the spoiler (plug-type spoiler-slot aileron), the effect of using a downgoing spoiler (deflected out of the wing lower surface) in conjunction with an upgoing spoiler (deflected out of the wing upper surface) as a means of increasing the aileron effectiveness was determined for the complete wing from the semispan data. The wing used in this investigation had a sweepback of 60° at the quarter-chord line, an aspect ratio of 2.0, a taper ratio of 0.6, and an NACA 65A006 airfoil section parallel to the free air stream. The spoiler ailerons were located along the 70-percent-chord line and had a span of 60 percent of the wing semispan.

COEFFICIENTS AND SYMBOLS

The moment coefficients of the wing are presented about the wind axes. At zero angle of attack the origin of the wind axes is at the intersection of the chord plane and the 25-percent mean-aerodynamic-chord station at the root of the model.

C_l rolling-moment coefficient, L/qSb

C_{l_u} uncorrected rolling-moment coefficient

C_n yawing-moment coefficient, N/qSb

c local wing chord parallel to plane of symmetry, ft

$\bar{c}$ wing mean aerodynamic chord, $\frac{2}{S}\int_0^{b/2} c^2 dy$, 0.255 ft

b twice span of semispan model, 0.50 ft

b_a aileron span measured perpendicular to plane of symmetry, ft

y lateral distance from plane of symmetry, ft

S twice area of semispan model, 0.125 sq ft

L rolling moment resulting from spoiler aileron projection about X-axis, ft-lb

N	yawing moment resulting from spoiler aileron projection about Z-axis, ft-lb
q	free-stream dynamic pressure, $\frac{1}{2}\rho V^2$, lb/sq ft
V	free-stream velocity, ft/sec
ρ	mass density of air, slugs/cu ft
α	geometric angle of attack of chord plane at root of model, deg
δ_s	spoiler aileron projection, percent c; negative when projected above upper surface of wing
M	effective Mach number over wing semispan
M_l	local Mach number
M_a	average chordwise local Mach number
R	test Reynolds number based on $\bar{c}$

MODEL AND APPARATUS

The semispan wing (see fig. 1) had 60° sweepback of the quarter-chord line, an aspect ratio of 2.0, a taper ratio of 0.6, and an NACA 65A006 airfoil section parallel to the free air stream. The wing was made of $\frac{1}{8}$-inch steel covered with a bismuth and tin compound, and the trailing edge was made of brass.

The spoiler used for both aileron configurations was made of $\frac{1}{32}$-inch sheet steel to the dimensions shown in figure 2. This spoiler was located along the 70-percent-chord line of the wing and was pivoted about the 50-percent-chord line of the wing. The plug-type spoiler-slot aileron had a 0.02-chord gap behind the spoiler which was sealed only at zero deflection of the spoiler. The retractable spoiler aileron configuration was identical to the plug-type spoiler-slot aileron configuration except that the 0.02-chord gap was sealed for all spoiler deflections. The general arrangement of both ailerons is shown in figure 2 and described in reference 7.

The model was mounted on an electrical strain-gage balance wired to a calibrated galvanometer in order to measure the aerodynamic forces and moments. The balance was located in a chamber within the bump, and the wing was mounted to the balance through a turntable on the surface of the bump. Figure 3 shows the arrangement of the model, the turntable, and the sponge seal used to prevent air flow around the root chord of the wing.

CORRECTIONS

The test data have not been corrected for jet-boundary effects or for blockage corrections. These corrections were felt to be negligible inasmuch as the model was small relative to the tunnel. The twisting and deflection effects determined by static load tests were found to be negligible and were not applied. The reflection-plane corrections shown in figure 4 were obtained from reference 2 and were applied to the rolling-moment data.

TEST TECHNIQUE

The tests were made in the Langley high-speed 7- by 10-foot tunnel using an adaptation of the NACA wing-flow technique for obtaining transonic speeds. The technique used involves placing the model in the high-velocity flow field generated over the curved surface of a bump on the tunnel floor (see ref. 3).

Typical contours of local Mach number in the vicinity of the model location on the bump are shown in figure 5. The contours indicate that there was a Mach number variation of 0.03 to 0.05 over the wing semispan in the M range investigated. The long dashed lines in figure 5 indicate a local Mach number 5 percent below the maximum value and represent the estimated extent of the bump boundary layer. The effective test Mach number was obtained from contour charts similar to those presented in figure 5 by using the relationship

$$M = \frac{2}{S} \int_0^{b/2} cM_a \, dy$$

The variation of Reynolds number with Mach number is shown in figure 6. The boundaries in the figure indicate the probable range in Reynolds number caused by variations in test conditions during the course of the investigation.

The data were obtained through a Mach number range of 0.619 to 1.167 and an angle-of-attack range of -2° to 18°.

DISCUSSION

The aerodynamic characteristics in pitch of the subject wing were not obtained for this investigation but are presented in reference 8 through the transonic speed range and an angle-of-attack range from -2° to 8°.

Lateral-control data obtained by projection of the retractable spoiler and plug-type spoiler-slot ailerons are presented in figures 7 and 8, respectively, at various angles of attack and Mach numbers. A portion of these data have been replotted on figure 9 at spoiler aileron projections of -0.011 to -0.056 at angles of attack of -2°, 6°, and 14°.

The variation of the rolling-moment coefficient of the retractable spoiler aileron with angle of attack is shown in figure 7 for the Mach number range investigated. It can be seen from this figure that the aileron effectiveness of the retractable spoiler aileron is generally less at the very high angles of attack than in the low angle-of-attack range (near zero) through this Mach number range. Below a Mach number of 0.959, the plug-type spoiler-slot aileron effectiveness (figs. 8 and 9) generally decreased with increase in angle of attack up to an angle of attack of approximately 6° and considerably increased with angle of attack above about 6° angle of attack. Chordwise pressure distributions obtained on a 35° sweptback wing equipped with plug-type spoiler-slot ailerons (ref. 5) indicated that the air flow was separated over the upper surface near the wing leading edge at angles of attack of 12° to 16° and was, therefore, less affected by spoiler aileron projection in the separated flow region. The pressure distributions of reference 5 indicate that the plug-type spoiler-slot aileron would be more effective than the retractable spoiler aileron, particularly at the higher angles of attack since the air flow through the slot behind the plug-type spoiler-slot aileron would cause a reduction in lift on the lower surface of the wing.

Above a Mach number of 0.959, the slot behind the plug-type spoiler-slot aileron lost most of its effectiveness; therefore, the rolling effectiveness of the plug-type spoiler-slot aileron (figs. 8 and 9) obtained at the higher angles of attack was not as large as the effectiveness obtained at the higher angles of attack below this Mach number. The plug-type spoiler-slot aileron, however, generally had more effectiveness than the retractable spoiler aileron throughout the Mach number and angle-of-attack ranges investigated.

A decrease in effectiveness (noted previously on the unswept wing of ref. 4) sometimes occurred when the lower edge of both the retractable spoiler and plug-type spoiler-slot ailerons emerged from the wing (above about -0.05c projection, figs. 7 and 8). The decrease noted in some instances was probably caused by air flow through the space between the upper surface of the wing and the lower edge of the spoiler, which tends to effect a partial pressure recovery over the wing rearward of the spoiler at these large projections.

The use of a downgoing retractable spoiler aileron on one wing in conjunction with an upgoing spoiler on the other wing would increase the aileron effectiveness at the lower angles of attack (less than about 10°) but would result in a decrease or reversal in the aileron effectiveness at the higher angles of attack as indicated from the data for the retractable spoiler aileron shown in figure 7. The plug-type spoiler-slot aileron would be essentially sealed in the positive projection range (downgoing) and would be comparable with the retractable spoiler aileron.

The yawing-moment coefficients were favorable at 0° angle of attack for both the retractable spoiler and plug-type spoiler-slot ailerons (figs. 7 and 8). At a given projection the yawing moments became less favorable or slightly unfavorable with increase in angle of attack above about 3° but were generally favorable throughout the Mach number and angle-of-attack range investigated. At a given angle of attack in the low angle-of-attack range, the yawing moments generally became more favorable with increase in spoiler projection (fig. 9). The use of both upgoing and downgoing spoilers on opposite wings would result in less favorable yawing moments for all flight conditions.

CONCLUSIONS

A wind-tunnel investigation utilizing the transonic-bump technique was made to determine the lateral control characteristics of retractable spoiler and plug-type spoiler-slot ailerons on a wing with the quarter-chord line sweptback 60°, an aspect ratio of 2, a taper ratio of 0.6, and an NACA 65A006 airfoil section. The results of the investigation led to the following conclusions:

1. The plug-type spoiler-slot aileron was generally more effective in producing roll than the retractable spoiler aileron throughout the Mach number, projection, and angle-of-attack ranges investigated.

2. The plug-type spoiler-slot aileron exhibited a large increase in aileron effectiveness at the high angles of attack compared to the effectiveness at zero angle of attack up to a Mach number of 0.959.

3. The use of an upgoing spoiler aileron on one wing in conjunction with a downgoing spoiler on the other wing would increase the rolling effectiveness at low angles of attack but would result in a decrease or reversal in the spoiler aileron effectiveness at the high angles of attack.

4. The yawing moments were generally favorable for both the retractable and plug-type spoiler-slot ailerons.

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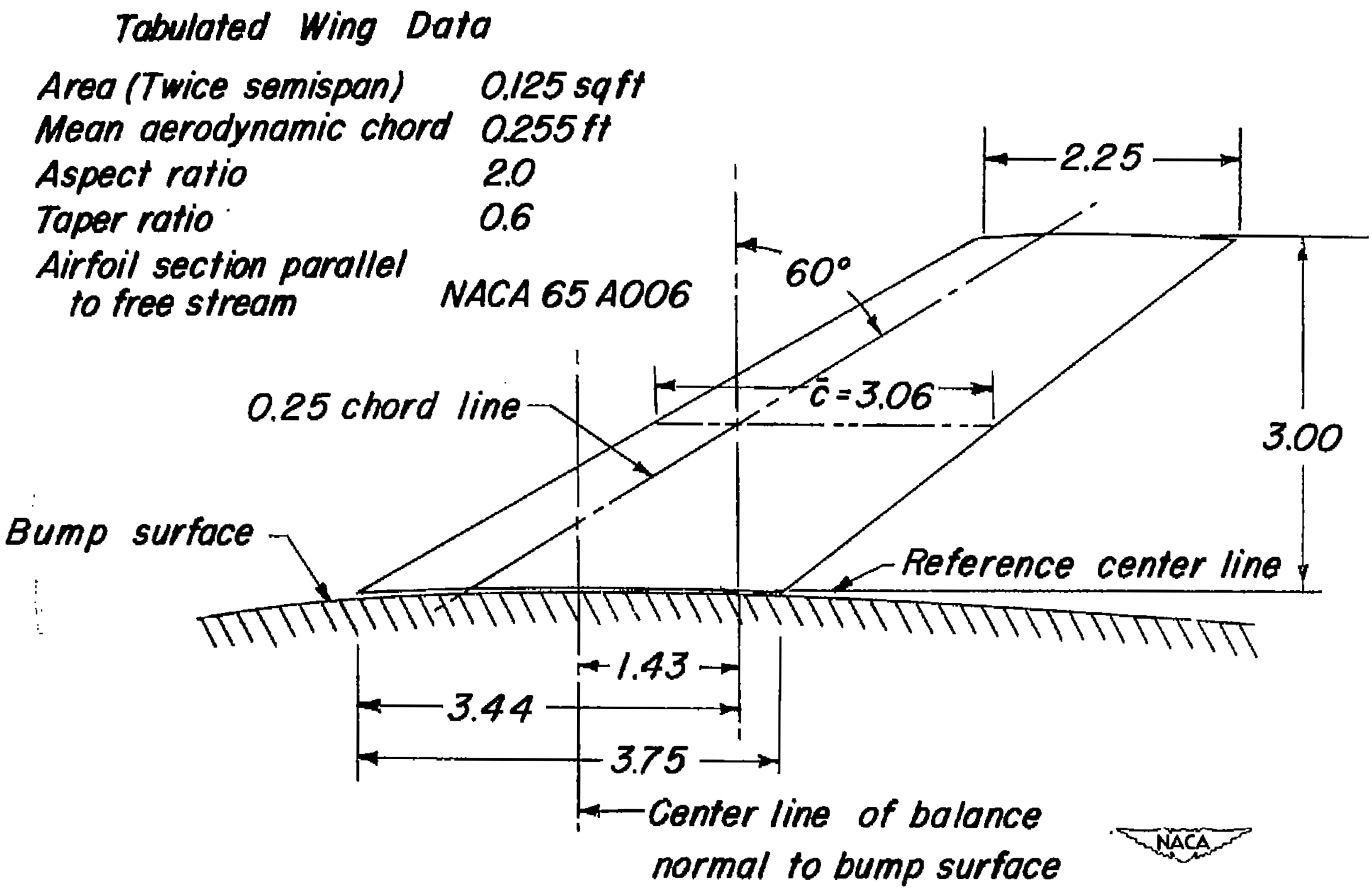

Figure 1.- Plan form and dimensions of 60° sweptback wing with aspect ratio 2 and taper ratio 0.6. All dimensions in inches unless otherwise noted.

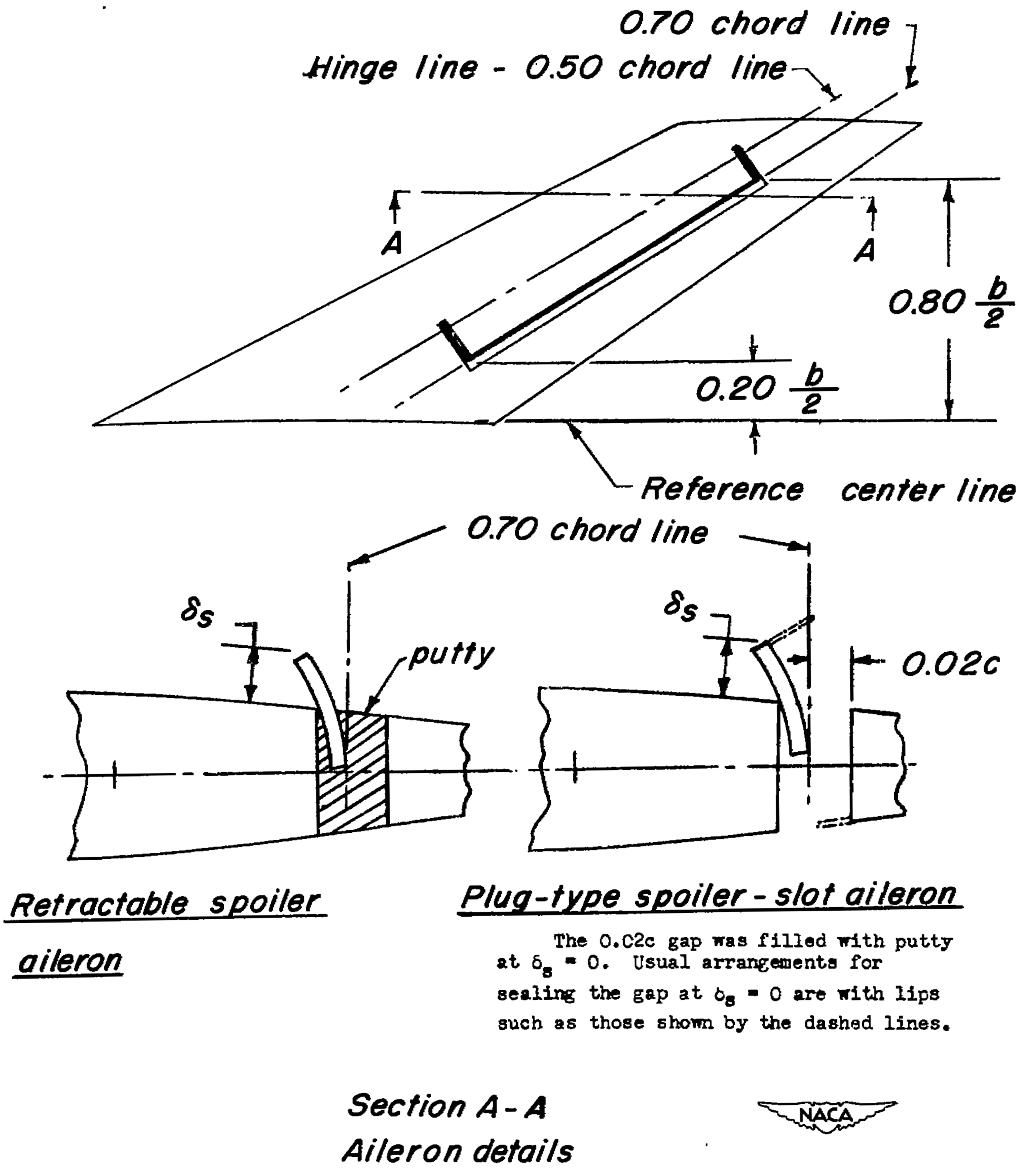

Figure 2.- Location and dimensions of the retractable spoiler aileron and plug-type spoiler-slot aileron.

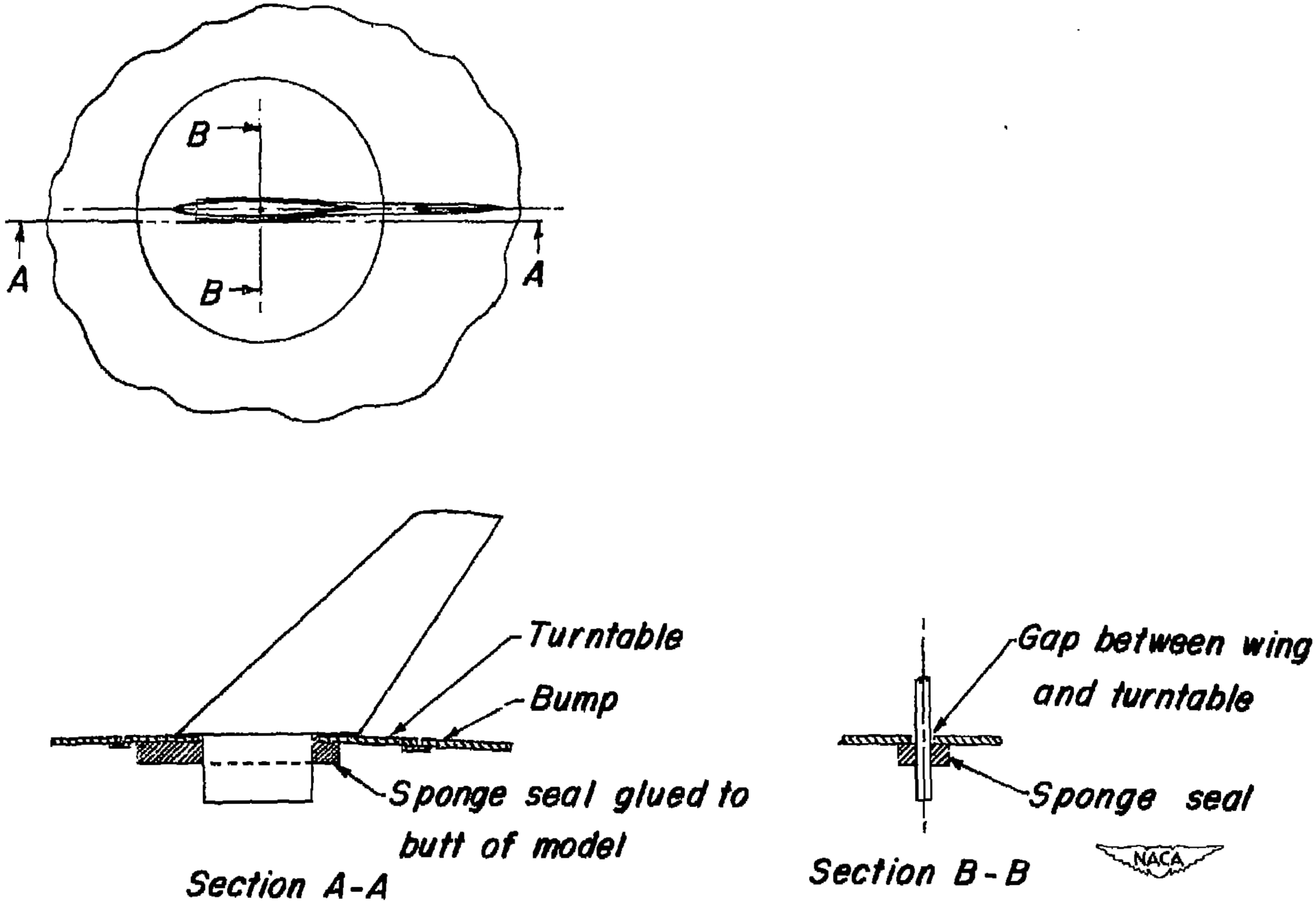

Figure 3.- Sketch of the wing, turntable, and sponge-seal arrangement.

⊙ c_l/c_{l_u} used for the configurations of this investigation

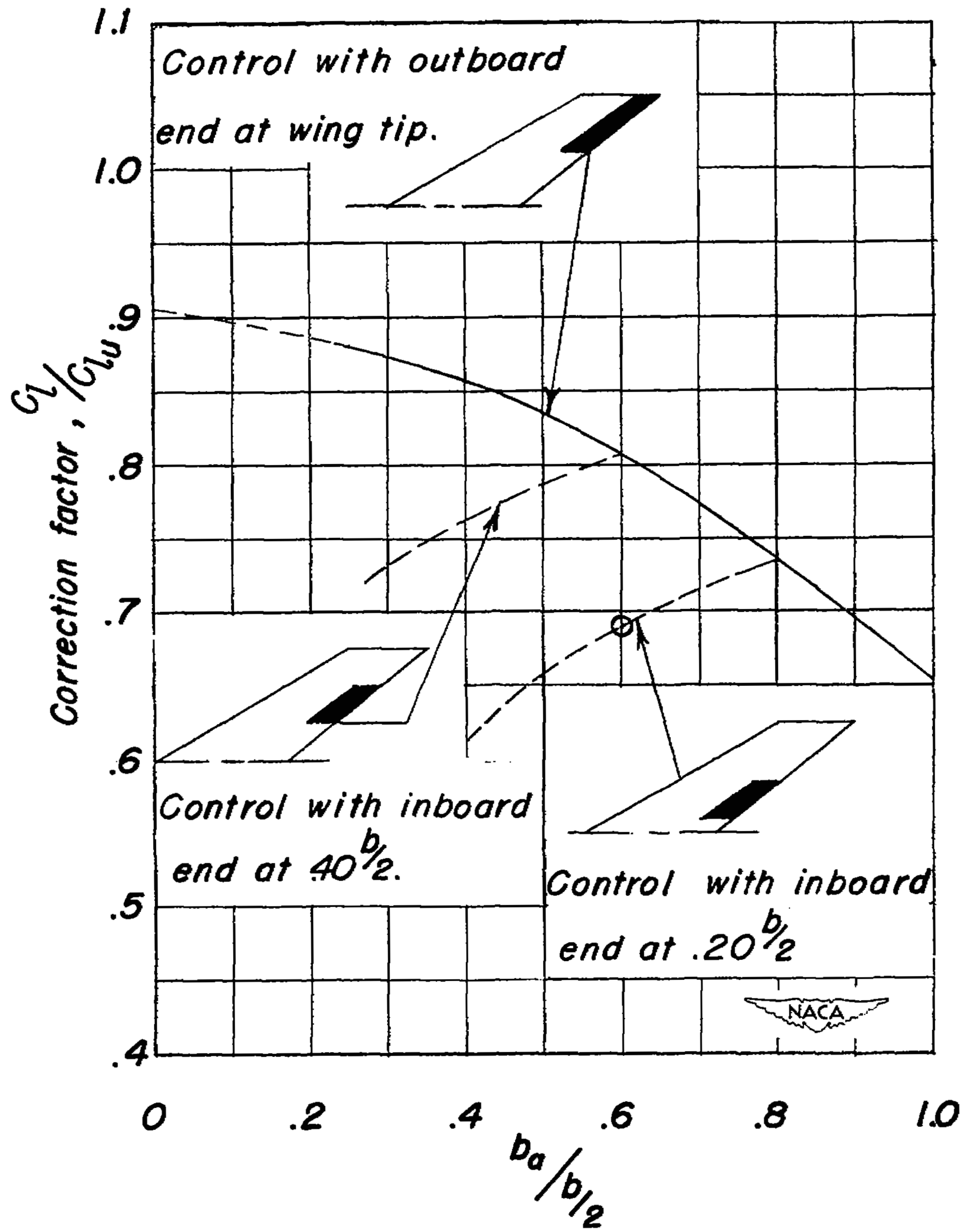

Figure 4.- Reflection-plane correction factors for inboard, center, and outboard controls of various spans for a wing of 60° of sweepback, aspect ratio 2, and taper ratio 0.6.

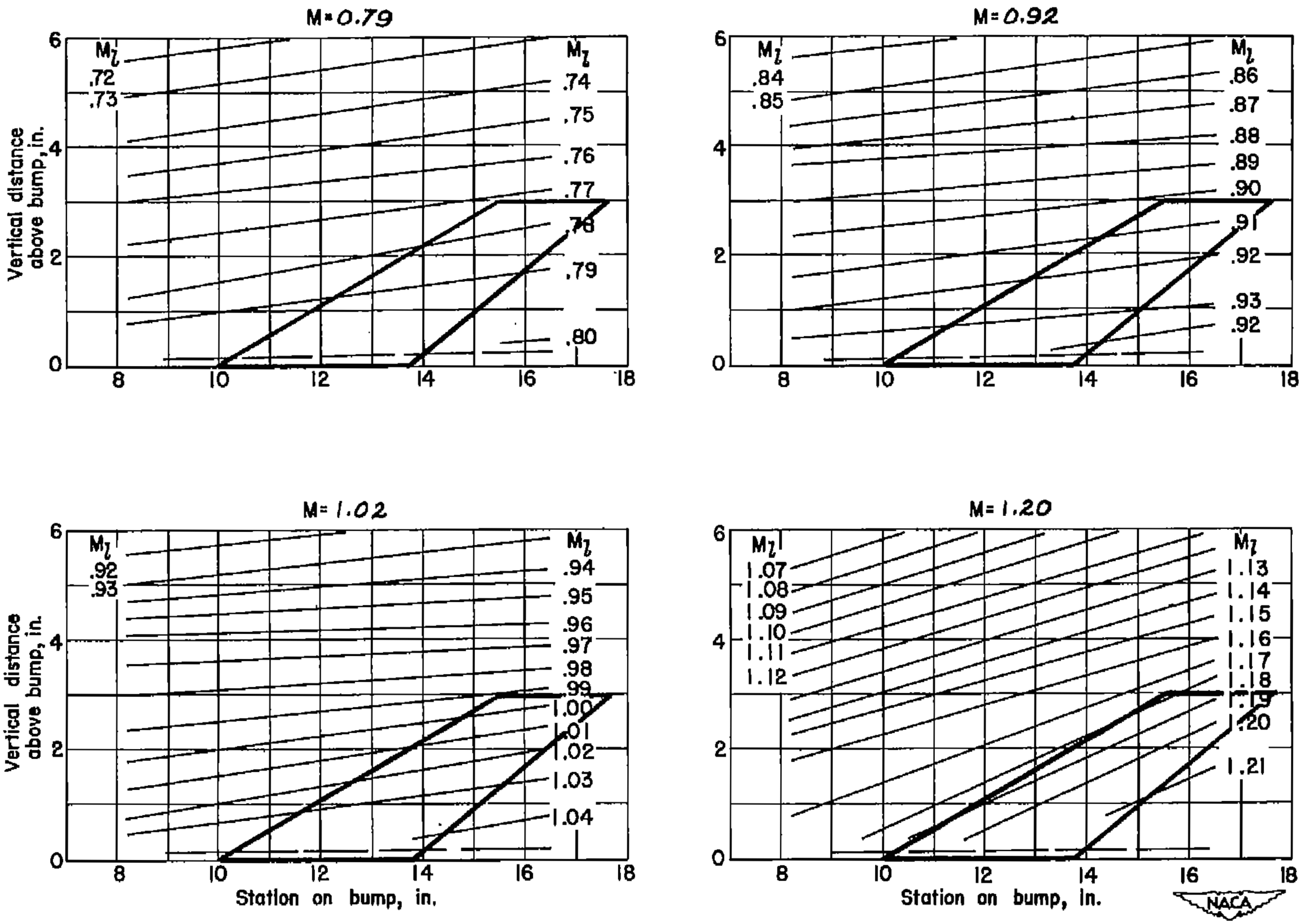

Figure 5.- Typical Mach number contours over transonic bump in region of model location.

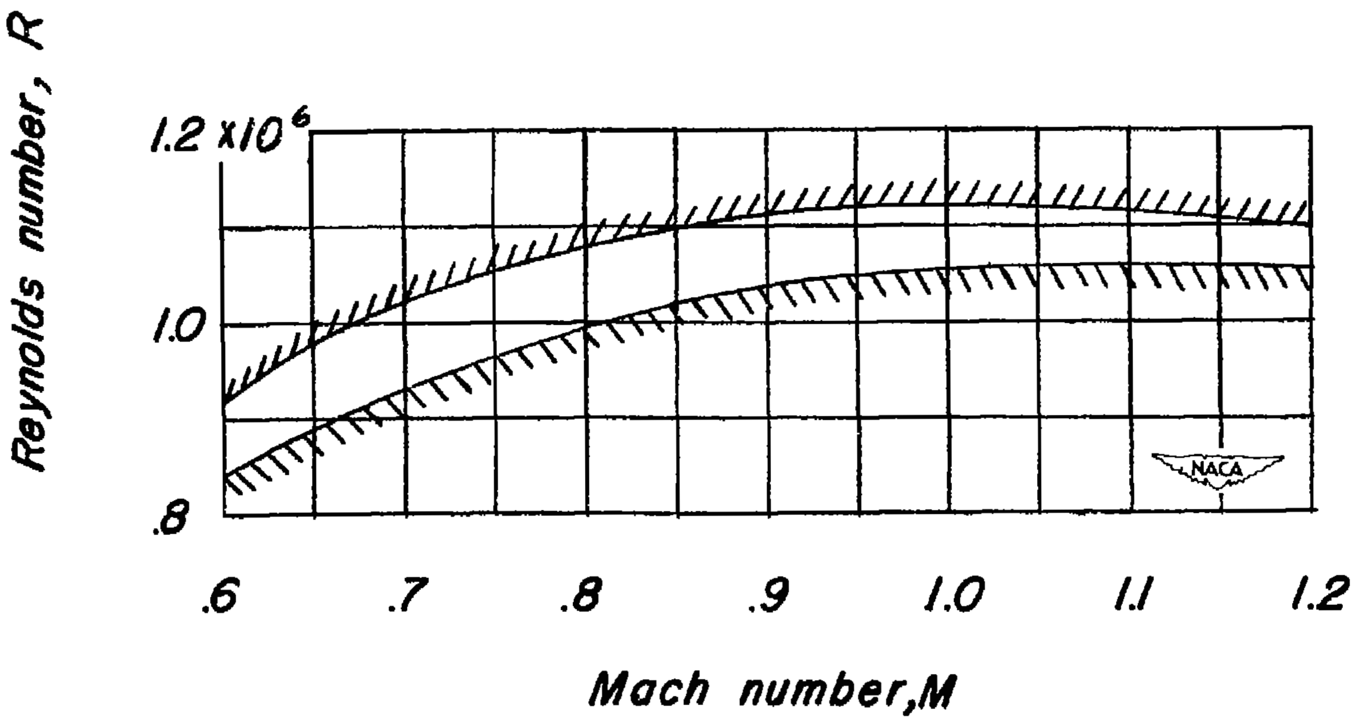

Figure 6.- Variation of test Reynolds number with Mach number for model with 60° sweptback wing, aspect ratio 2, taper ratio 0.6, and NACA 65A006 airfoil.

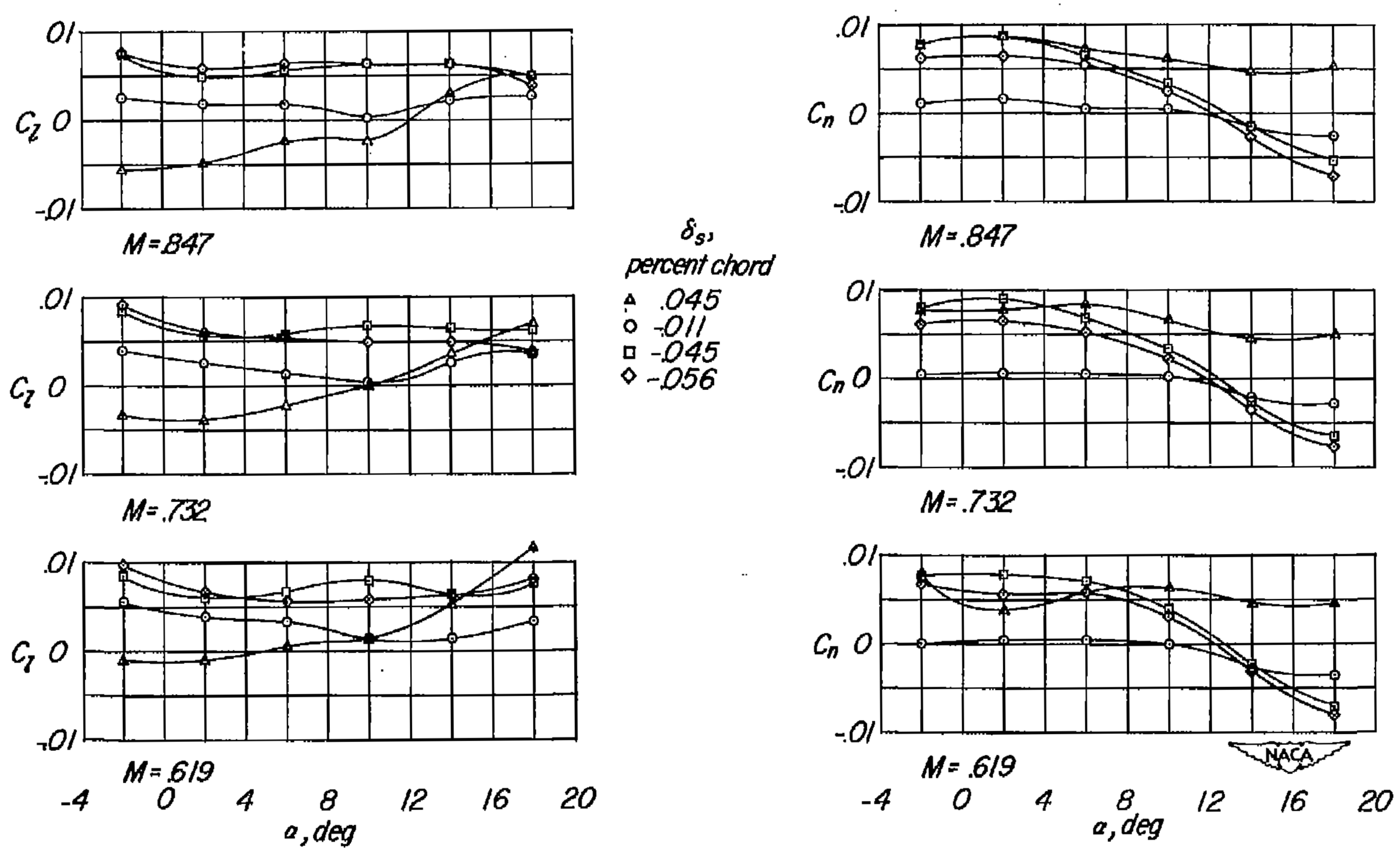

Figure 7.- The lateral control characteristics of the retractable spoiler aileron at various Mach numbers and angles of attack.

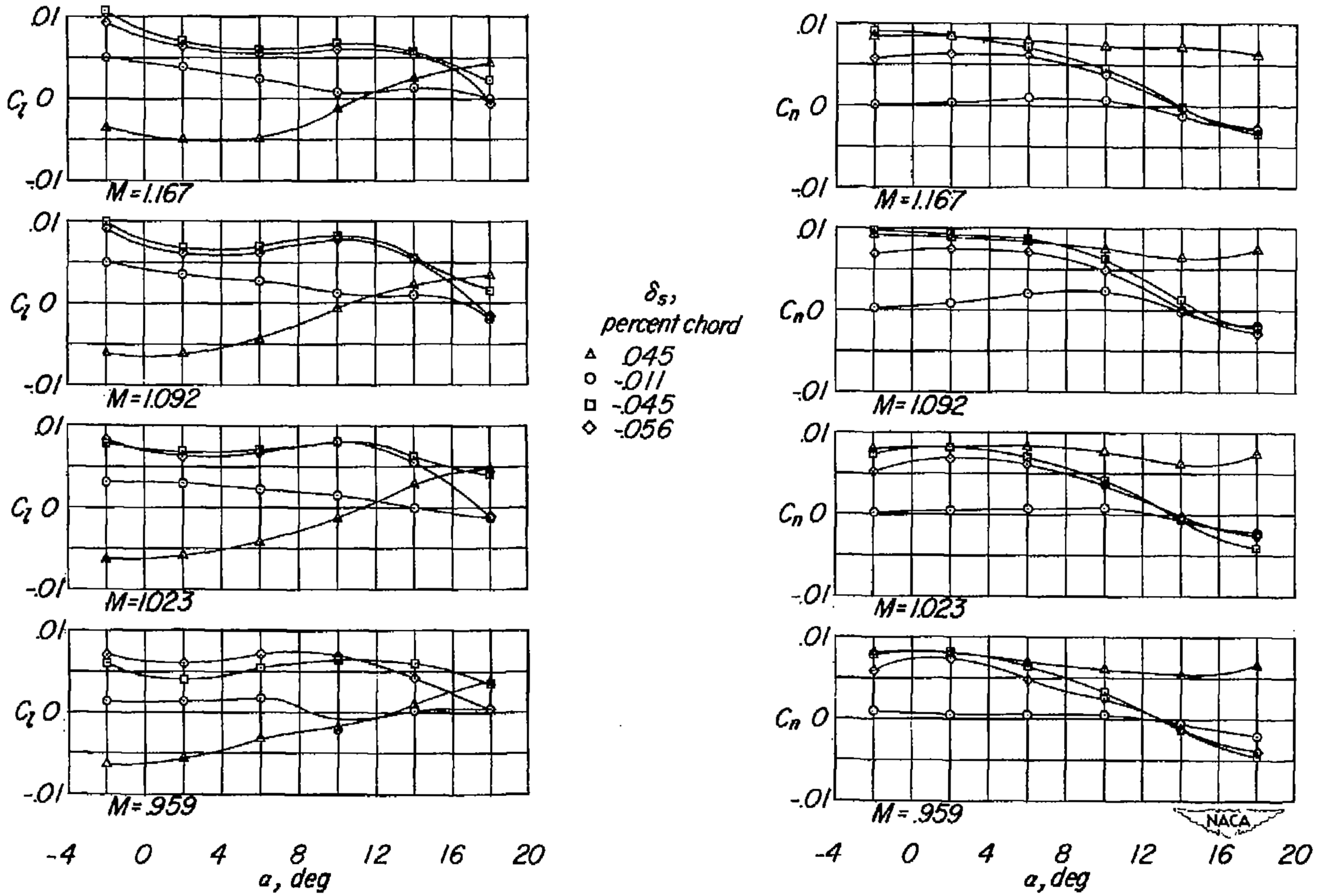

Figure 7.- Concluded.

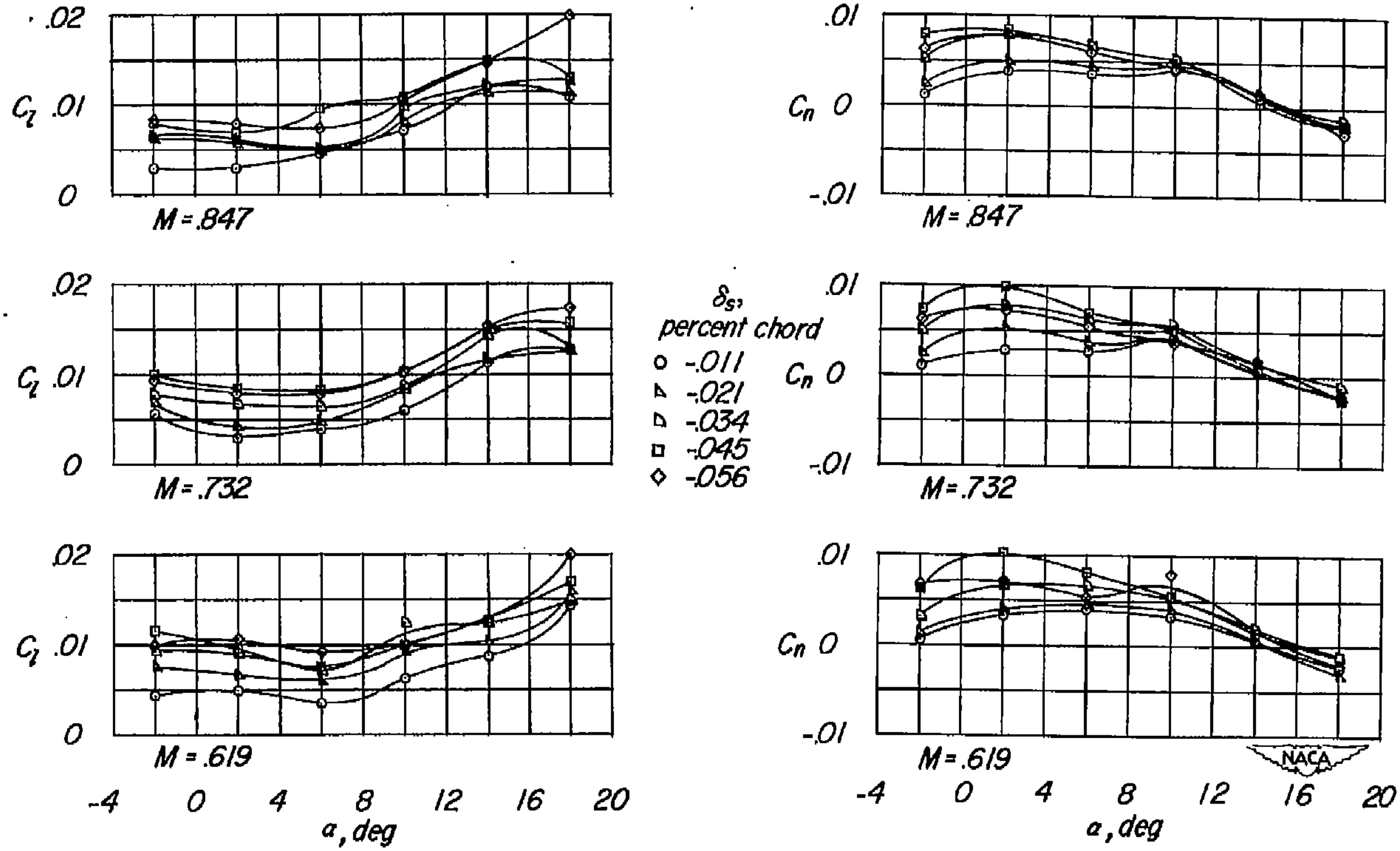

Figure 8.- The lateral control characteristics of the plug-type spoiler-slot aileron at various Mach numbers and angles of attack.

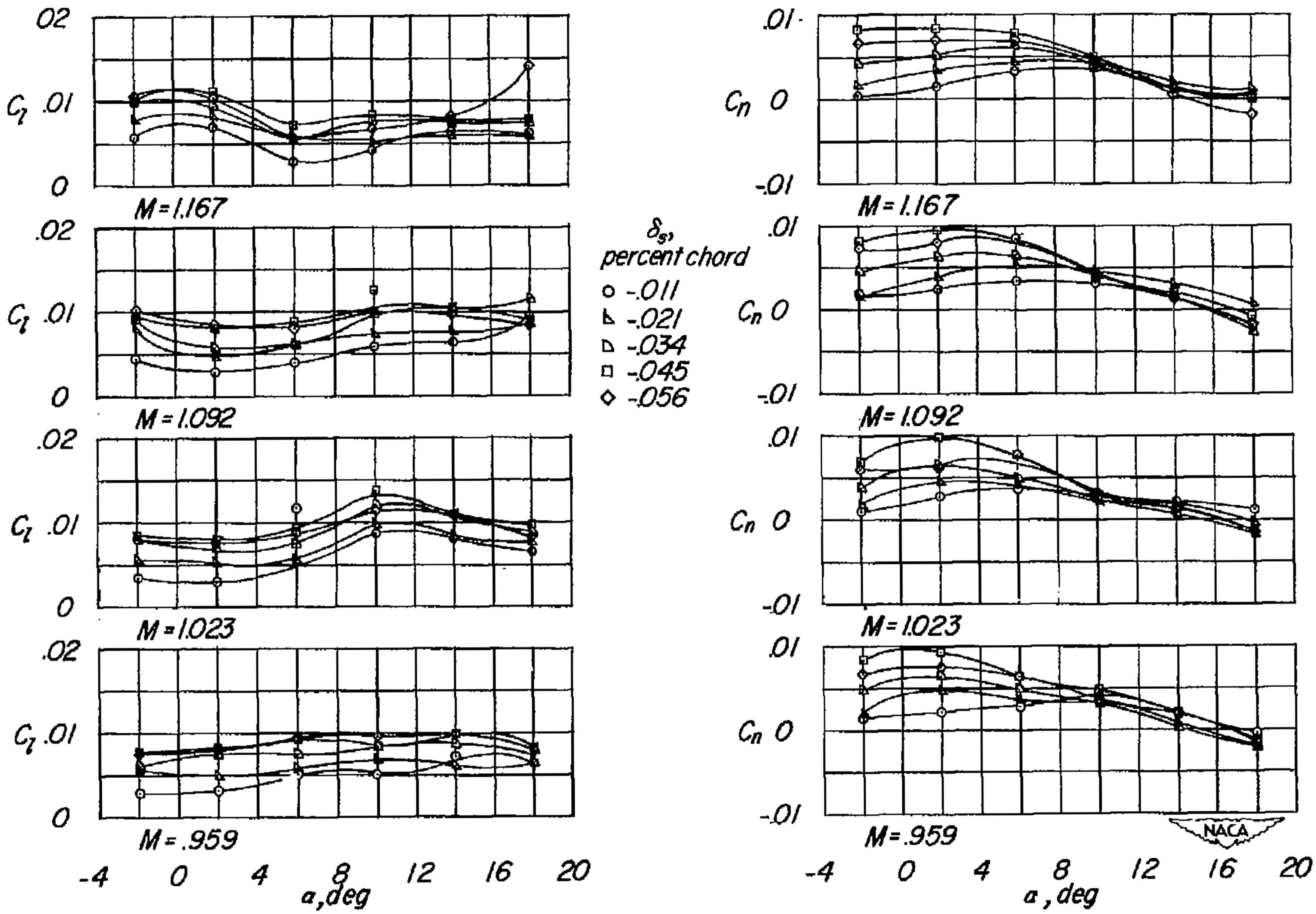

Figure 8.- Concluded.

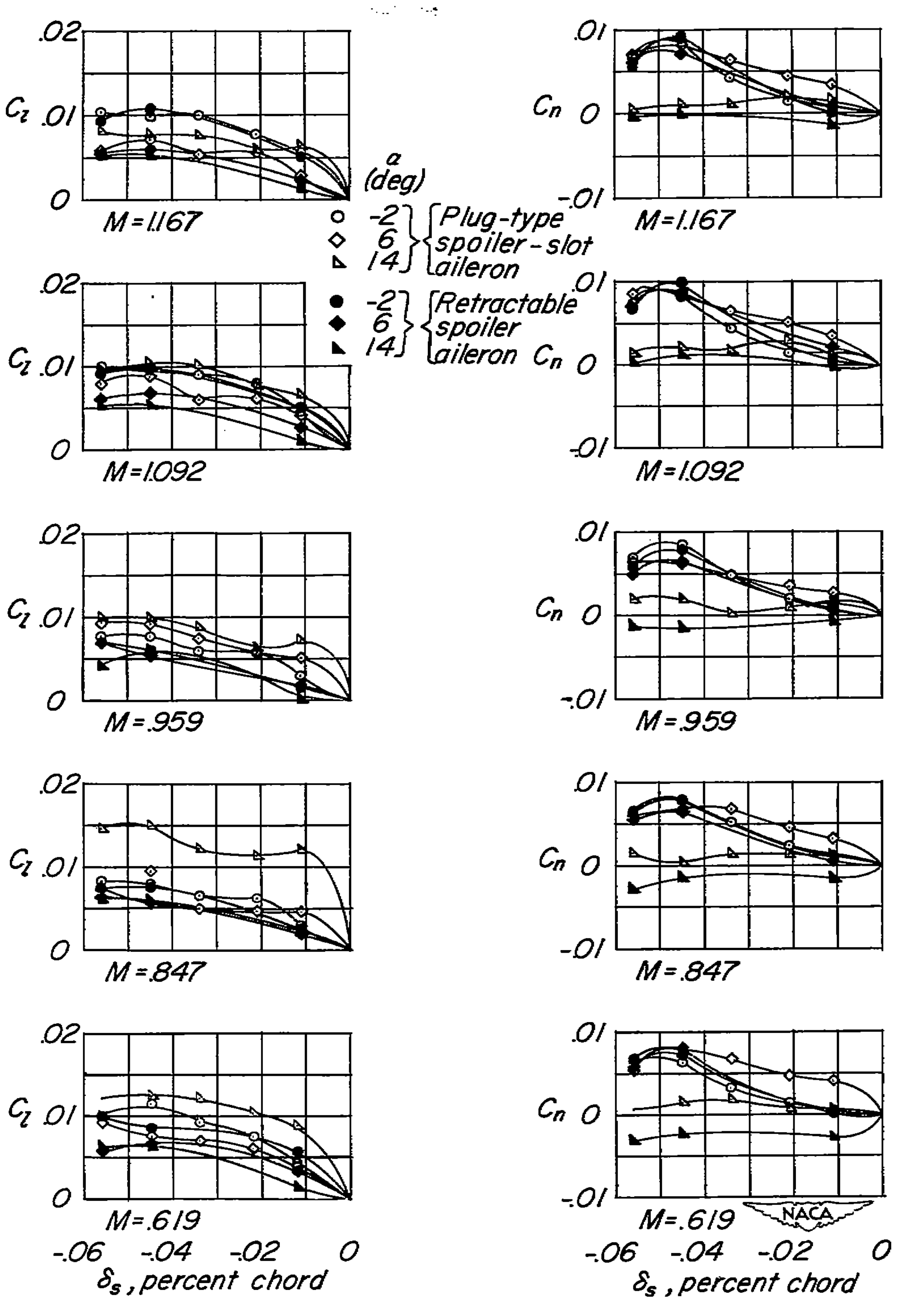

Figure 9.- Comparison of the lateral control characteristics of the retractable spoiler aileron and plug-type spoiler-slot aileron.

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